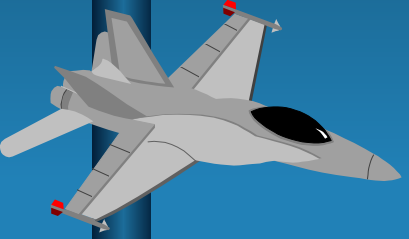
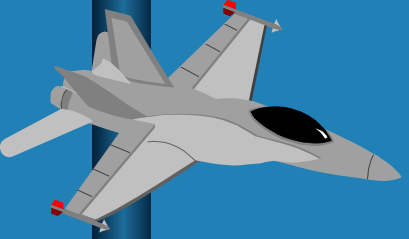


Flight Operations Risk Assessment System

FORAS Overview

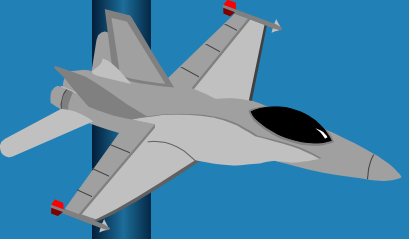
Morristown, New Jersey

August 17-18, 1999



FORAS Team Activities

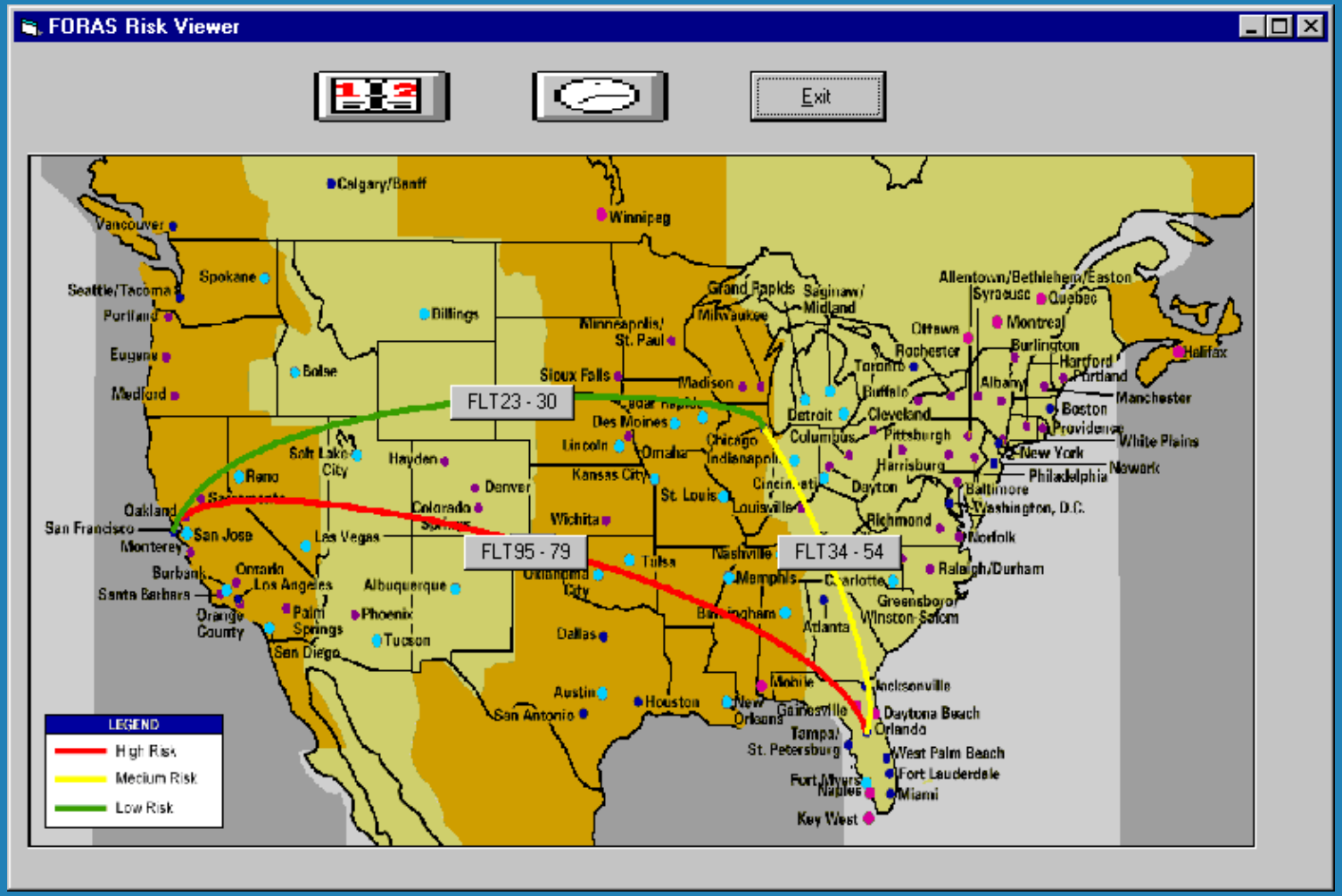
- Work officially began in March
- Progress to date
  - Model selection and development
  - Knowledge elicitation and representation
  - Systems analysis
  - System design (including coding and testing)
  - Weather database design and development



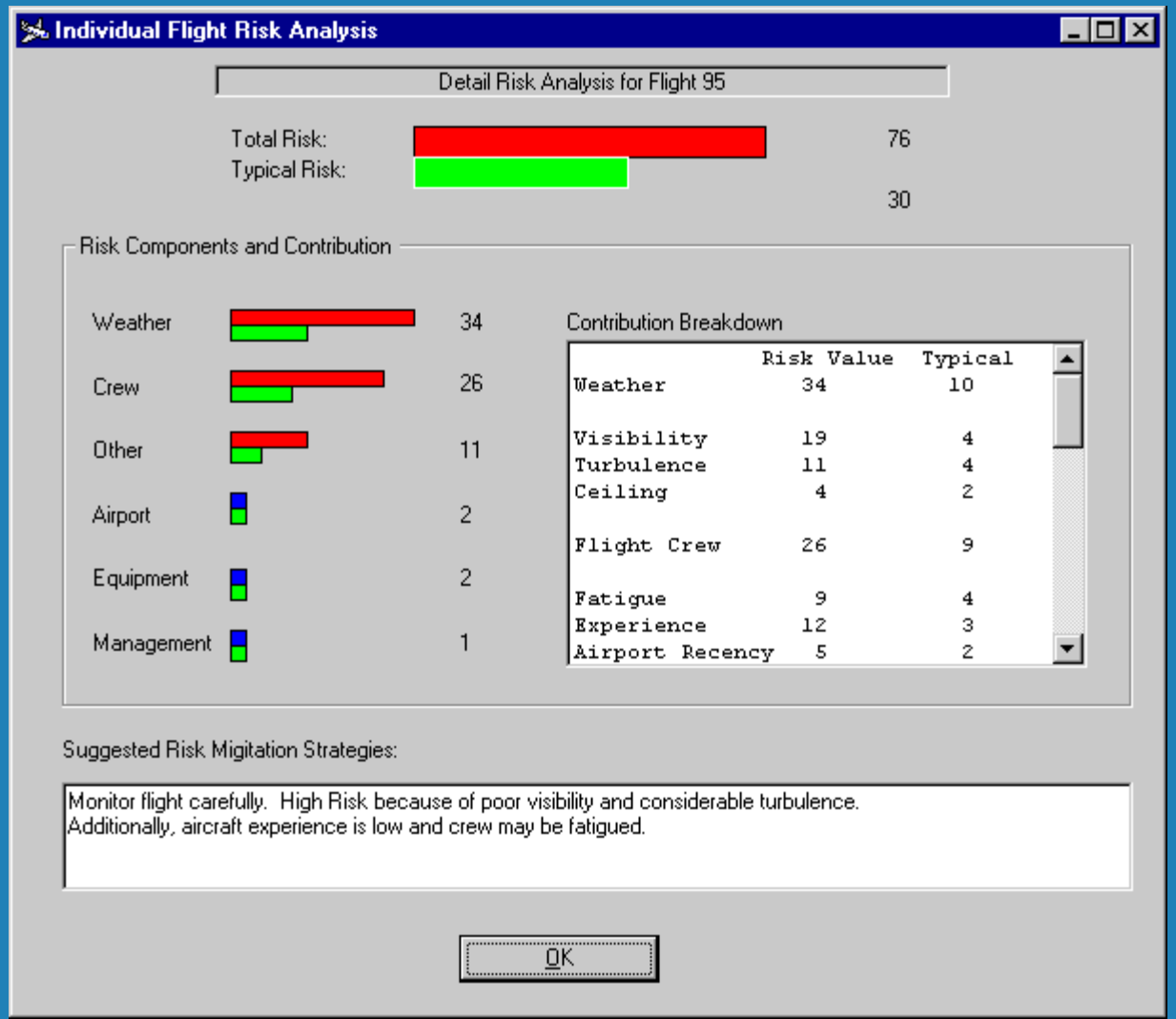
FORAS Personnel

	Model	Elicitation	Sys Anal	Sys Dev	Data	# Hrs
ERAU:						
I. Baig				X		360
R. Coutinho			X			240
J. George	X					40
D. Osborne	X	X	X		X	760
D. Ross	X	X		X	X	700
N. Tadayon	X		X	X		480
J. Watret		X				160
D. Whittaker	X				X	200
NCAR:						
D. Boyd		X			X	326
B. Brown					X	86
B. Mahoney			X			24
C. Chen					X	57
NRL:						
M. Hadjimichael	X		X		X	240

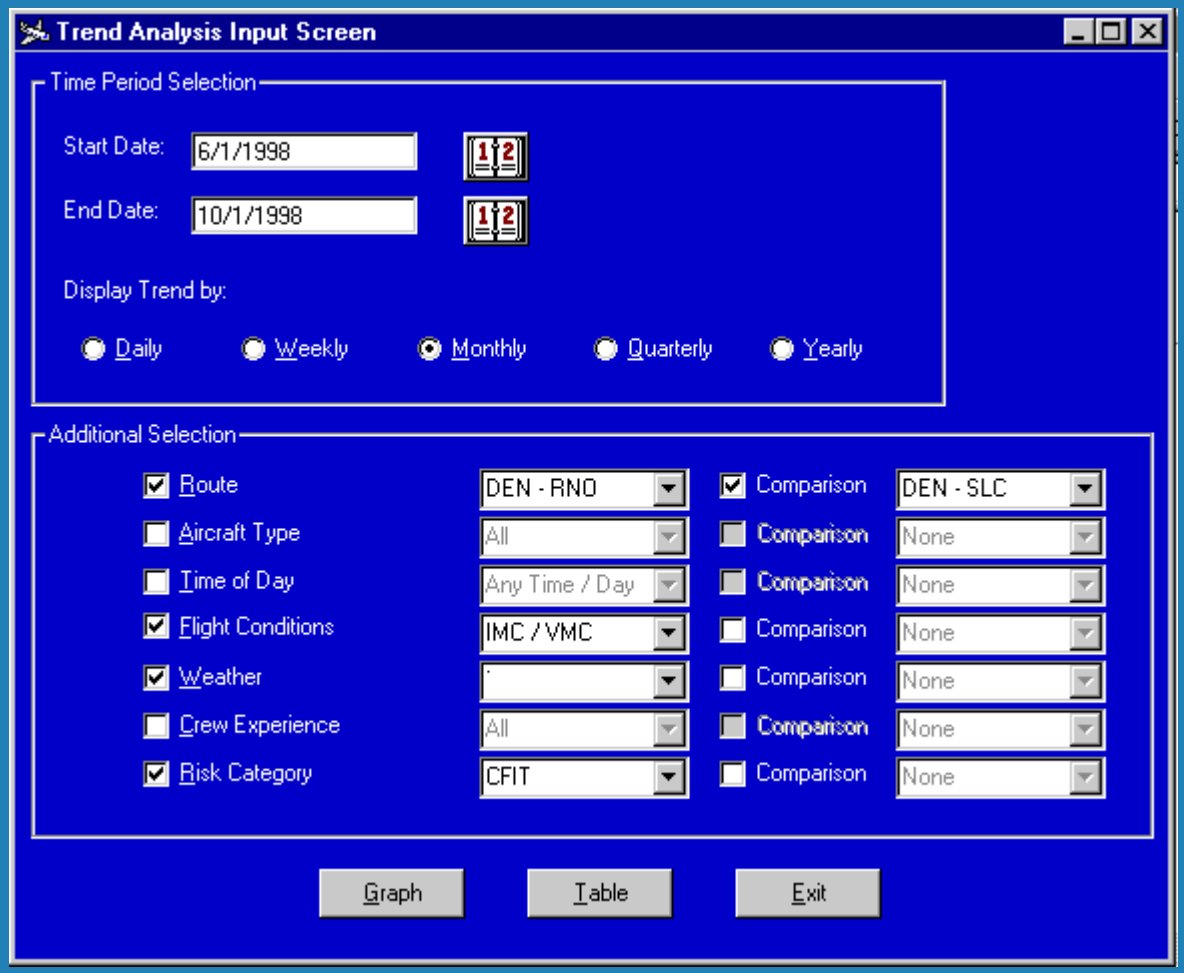
FORAS Input: Flight Ops



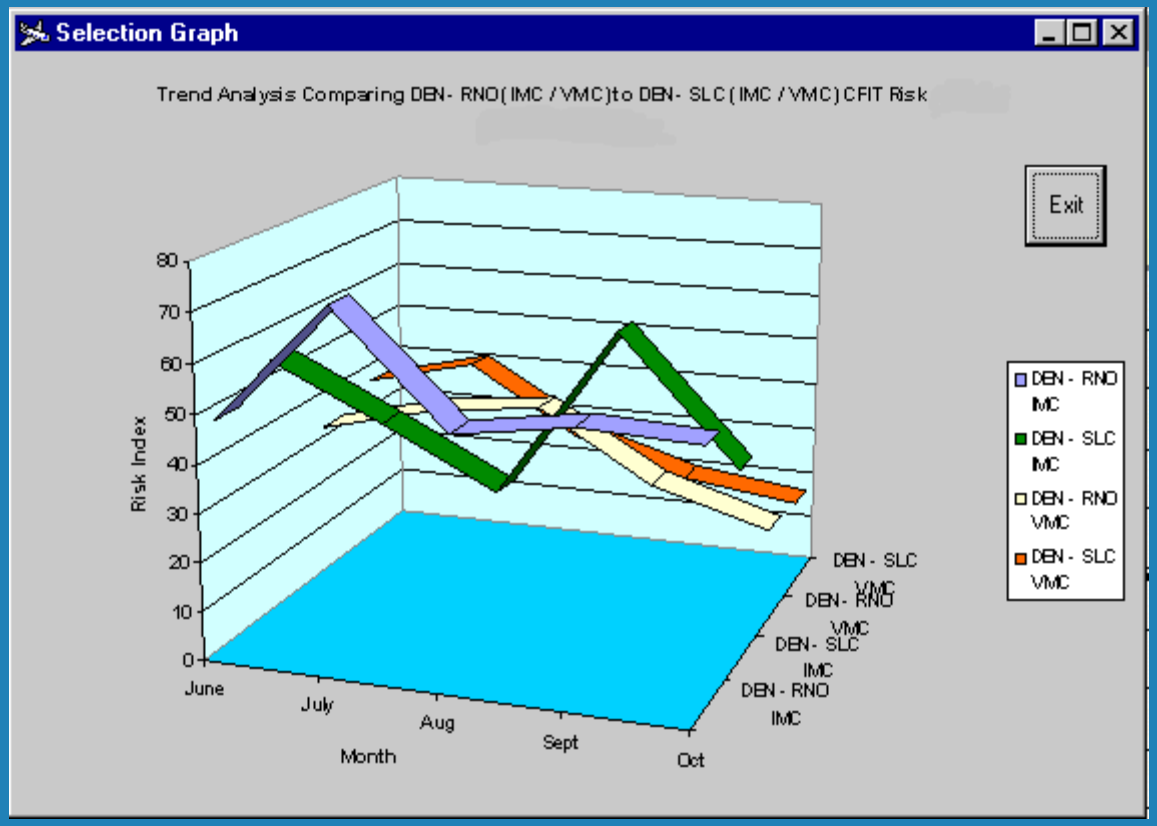
FORAS Output: Flight Ops



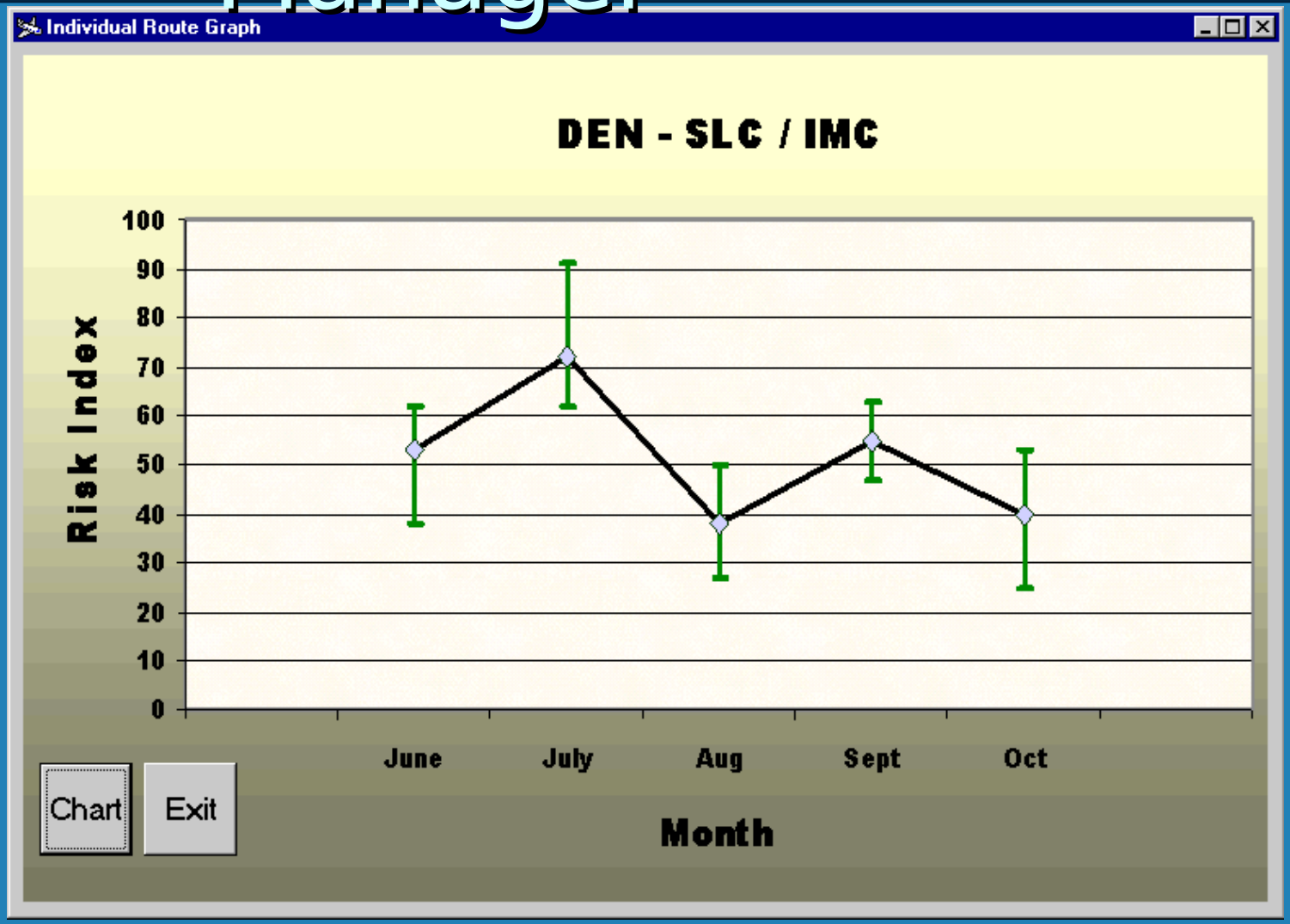
FORAS Input: Safety Manage



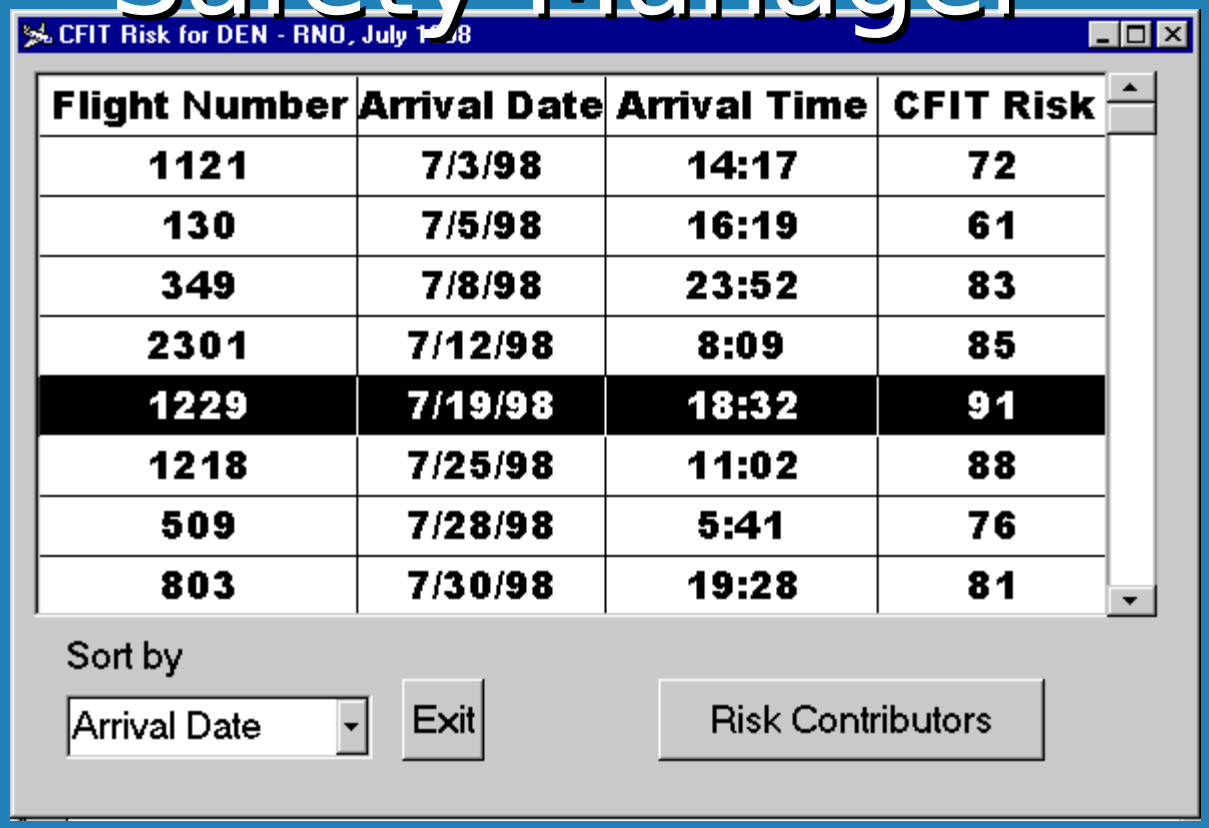
FORAS Output: Safety Manager

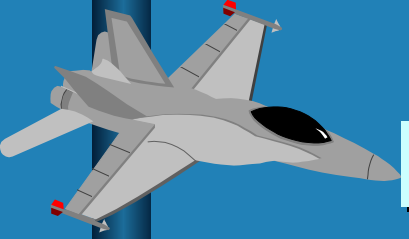


FORAS Output: Safety Manager



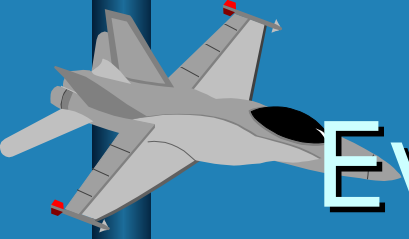
FORAS Output Flight Ops / Safety Manager





Industry Collaborations

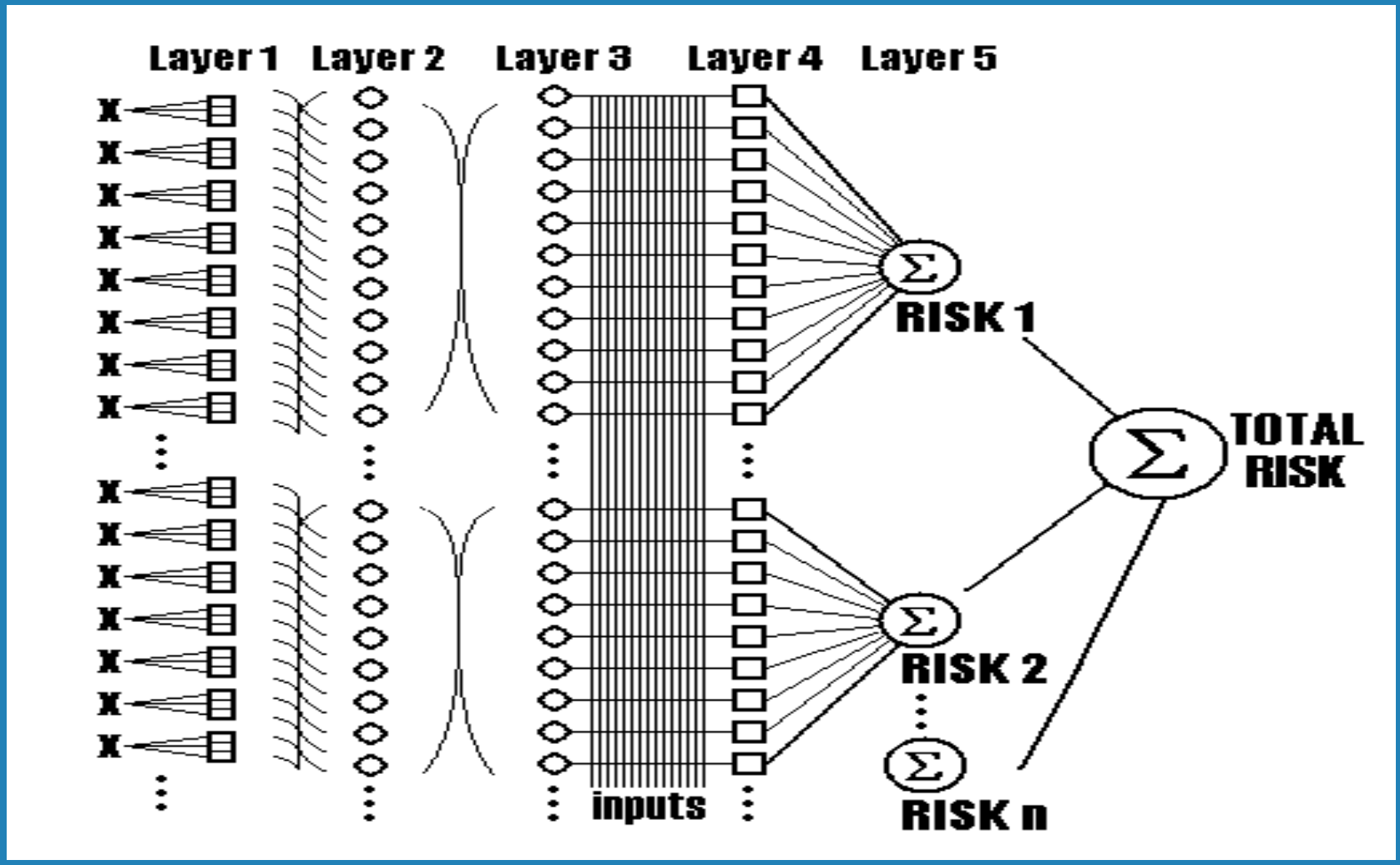
- UAL
  - Expert elicitation sessions: Pilots, Dispatchers, Flight Attendants
  - Data discussions: Information Systems, Meteorology, and Safety
- Airbus Industrie
  - Data discussions: Training and Flight Operations Support
  - Line Operations Monitoring System (LOMS) discussions: Training and Flight Operations Support
- ATC
  - Process discussions: Monterey and Daytona Beach



Evolution of FORAS Model

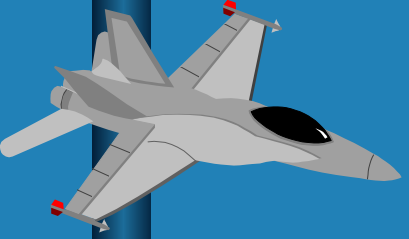
- Phase I
  - Identify significant inputs
  - Structure and prioritize inputs (AHP)
- Phase II
  - Elicit knowledge base from experts
  - Quantify knowledge base (fuzzy approach)
  - Model complex interactions (neural net)
  - Refine model parameters

Network Structure



FORAS Phase II Project Plan Status

FORAS PHASE II ACTIVITIES		SCHEDULED	SCHEDULED	(8/14/99)
	DURATION	START	FINISH	STATUS
Develop Concept of Operations for FORAS	46d	Mon 3/1/99	Mon 5/3/99	X
Revise Concept of Operations Document	2w	Tue 5/4/99	Fri 5/21/99	X
Develop Functional Requirements (Phase-2 System)	25d	Mon 5/3/99	Fri 6/4/99	X
Develop FORAS System Design (Model Component)	70d	Mon 3/1/99	Fri 6/4/99	X
Develop FORAS User Interface Design (Features/Function	35d	Mon 5/24/99	Fri 7/9/99	In Progress
FORAS Prototype Design Review	2d	Tue 7/13/99	Wed 7/14/99	In Progress
Data Gathering (Jump Seat Flights)	66d	Mon 3/1/99	Mon 5/31/99	X
Develop Process to Identify CFIT Experts	23d	Mon 3/1/99	Wed 3/31/99	X
Interview Experts	107d	Mon 4/5/99	Tue 8/31/99	X
Data Gathering (Airline) - Develop Airline Partnerships	132d	Mon 3/1/99	Tue 8/31/99	In Progress
Data Gathering (FAA Data)	132d	Mon 3/1/99	Tue 8/31/99	Not necessary
Develop Weather Climatologies (Ceiling & Visibility)	154d	Mon 3/1/99	Thu 9/30/99	In Progress
Develop Relational Database for Selected Airports	154d	Mon 3/1/99	Thu 9/30/99	In Progress
Software Development (Model Component)	141d	Fri 4/16/99	Fri 10/29/99	In Progress
Software Development (User Interface)	109d	Tue 6/1/99	Fri 10/29/99	In Progress
Software Integration Testing	44d	Fri 10/1/99	Wed 12/1/99	Not Started
Project Progress Review	2d	Tue 10/5/99	Wed 10/6/99	Not Started
FORAS Prototype System Shakedown	27d	Thu 12/2/99	Fri 1/7/00	Not Started
FORAS Prototype Demonstration	30d	Mon 1/10/00	Fri 2/18/00	Not Started
Prepare FORAS Phase-2 Project Report	20d	Mon 1/24/00	Fri 2/18/00	Not Started
Submit FORAS Phase-2 Project Report	0d	Fri 2/18/00	Fri 2/18/00	Not Started
Prepare FORAS Prototype Software for Delivery	20d	Mon 1/24/00	Fri 2/18/00	Not Started
Deliver Prototype FORAS Software	0d	Fri 2/18/00	Fri 2/18/00	Not Started
Phase-2 Project Review Meeting	3d	Tue 2/29/00	Thu 3/2/00	Not Started



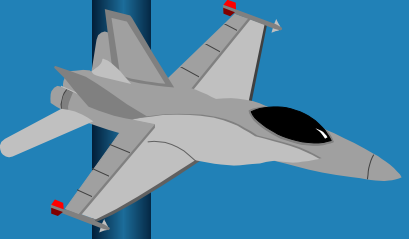
FORAS Vision

A system for the assessment and mitigation of risk
associated with flight operations.

A quantitative value indicating the relative risk lev
for various flight operations-related risks.

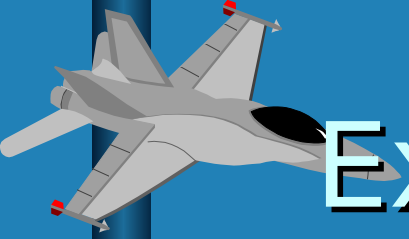
Examples: CFIT, TII (turbulence-induced injuries),
mid-air collision, approach&landing, loss of contro

Operations-level, regional, per-flight.
Summary levels: e.g. by airport, sector, equipmen



User Feature Overview

- Used by safety managers, dispatchers, and others;
- Both summary and real-time analyses: charts/graphs, statistics, system-integrated output;
- Multilevel analysis: “drill-down” exploration of risk structure;
- Multicategory risk analysis;
- Expert system-supplied mitigative strategies.

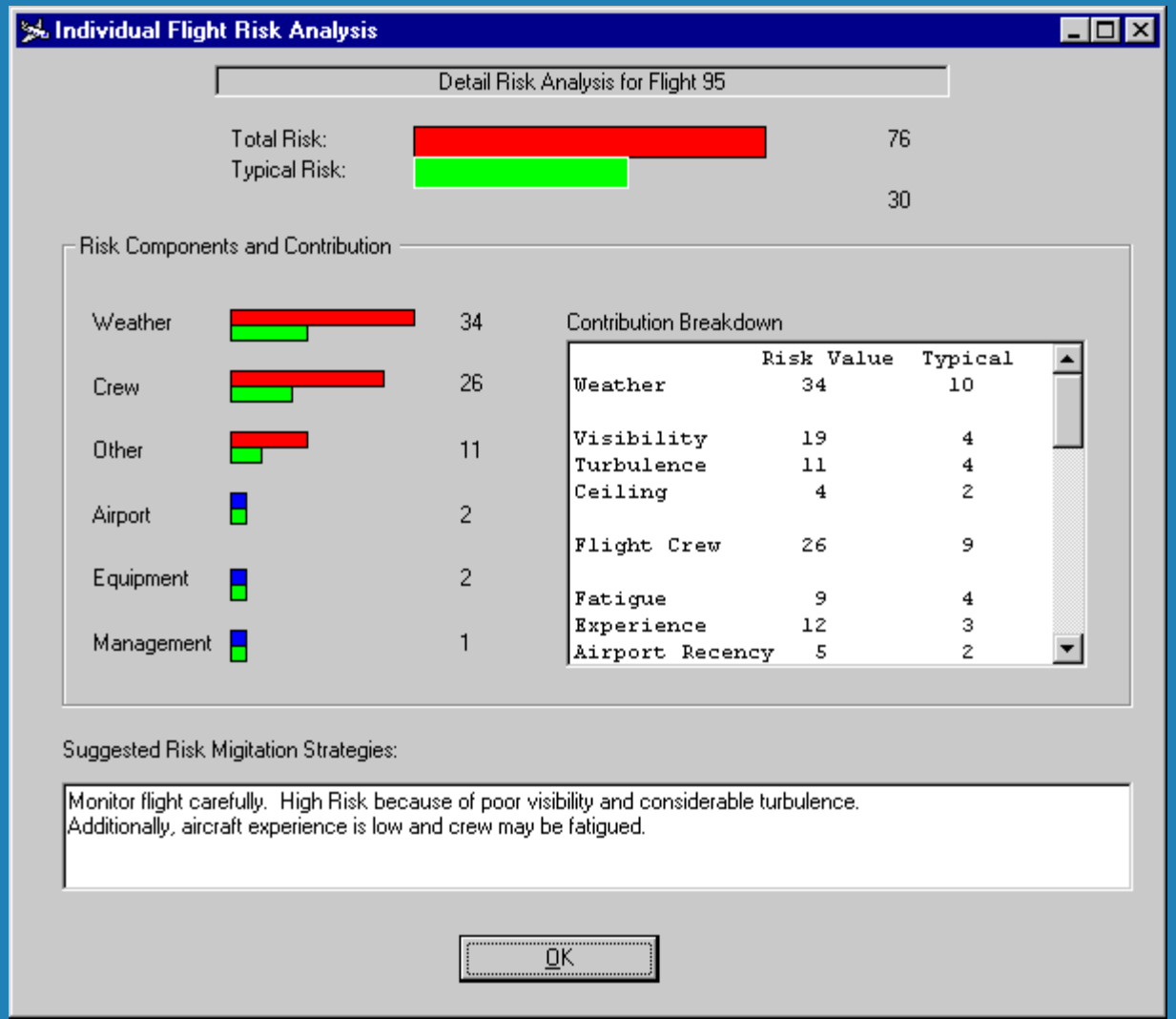


Example users and usage

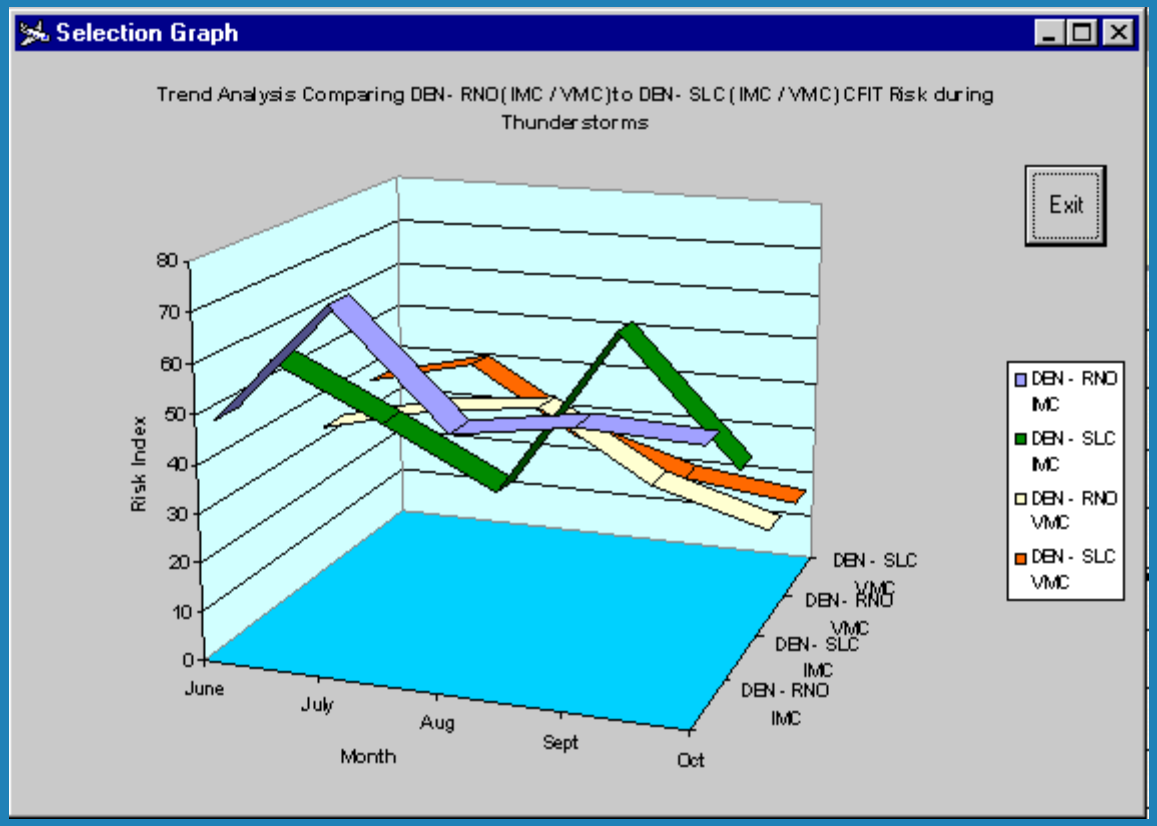
- Safety Manager examples:
  - operations-level analysis of CFIT risk,
  - approach&landing risk for all flights into MRY,
  - effect of route changes or crew scheduling policy on overall relative risk.

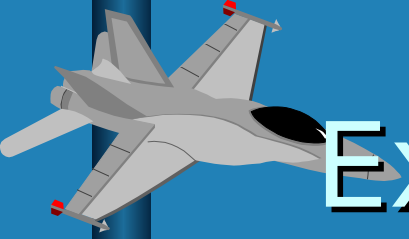
  - Make routing/scheduling decisions,
  - Analyze effects of some safety policy decisions,

FORAS Output: Flight Ops



FORAS Output: Safety Manager

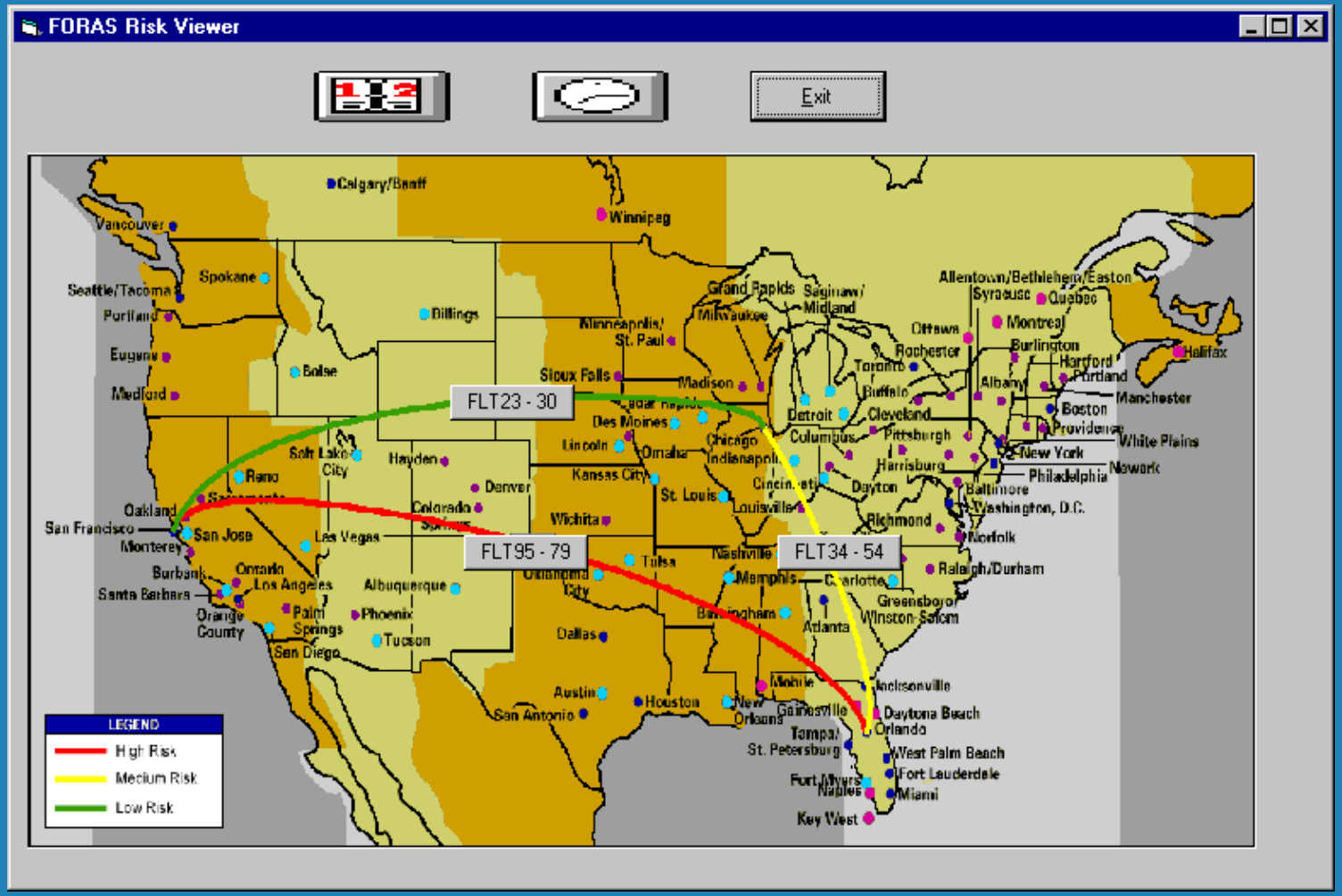




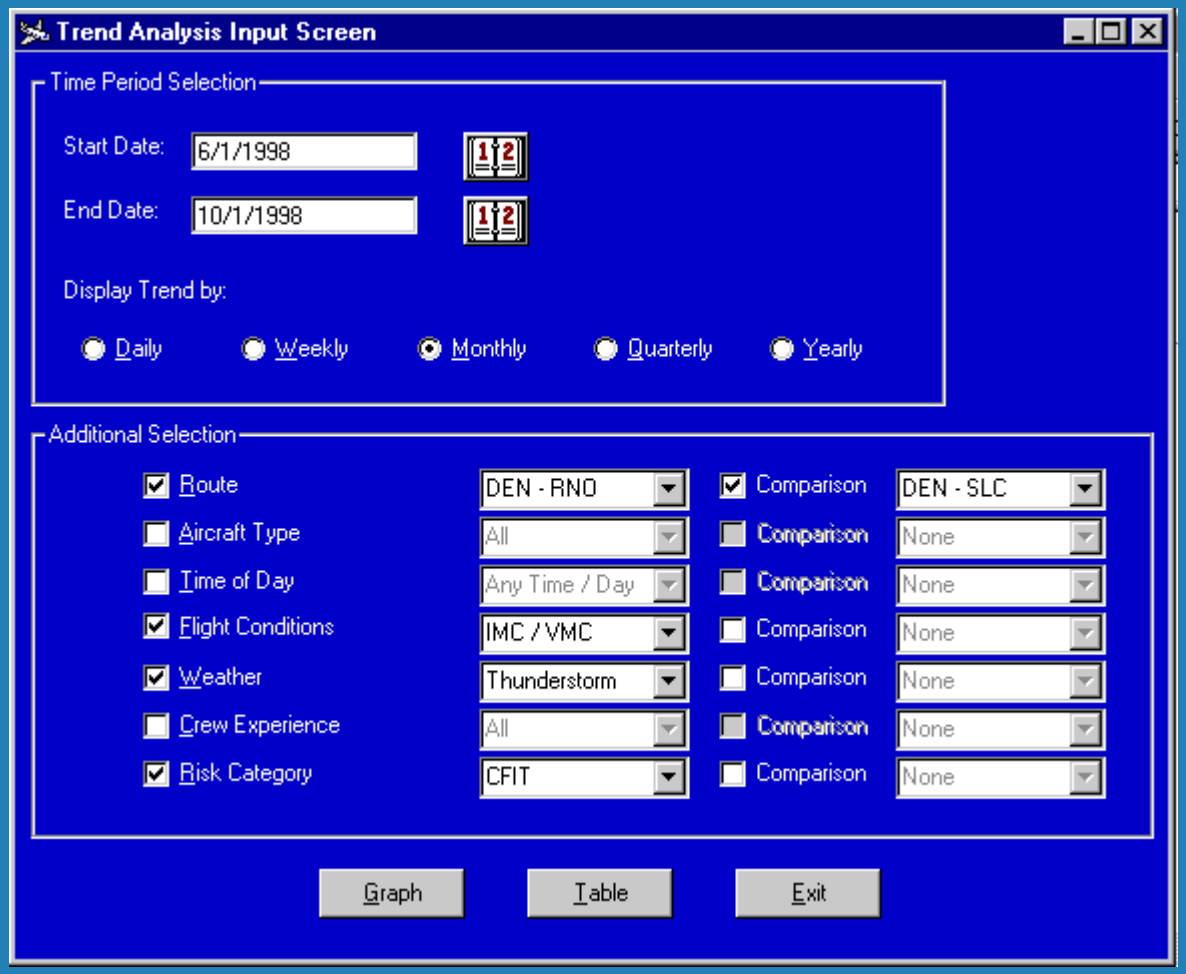
Example users and usage

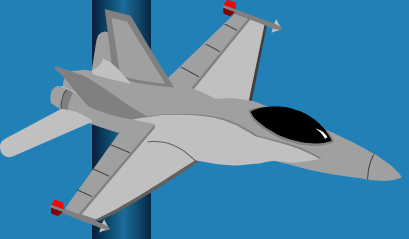
- Dispatcher: e.g.,
  - Overall relative risk for each of the day's flights.
  - Make real-time decisions about flight scheduling, routing, etc.
  - Identify high priority (high risk) flights before departure.

Input: Flight Ops



FORAS Output: Safety Manag

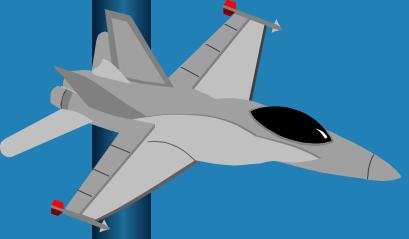




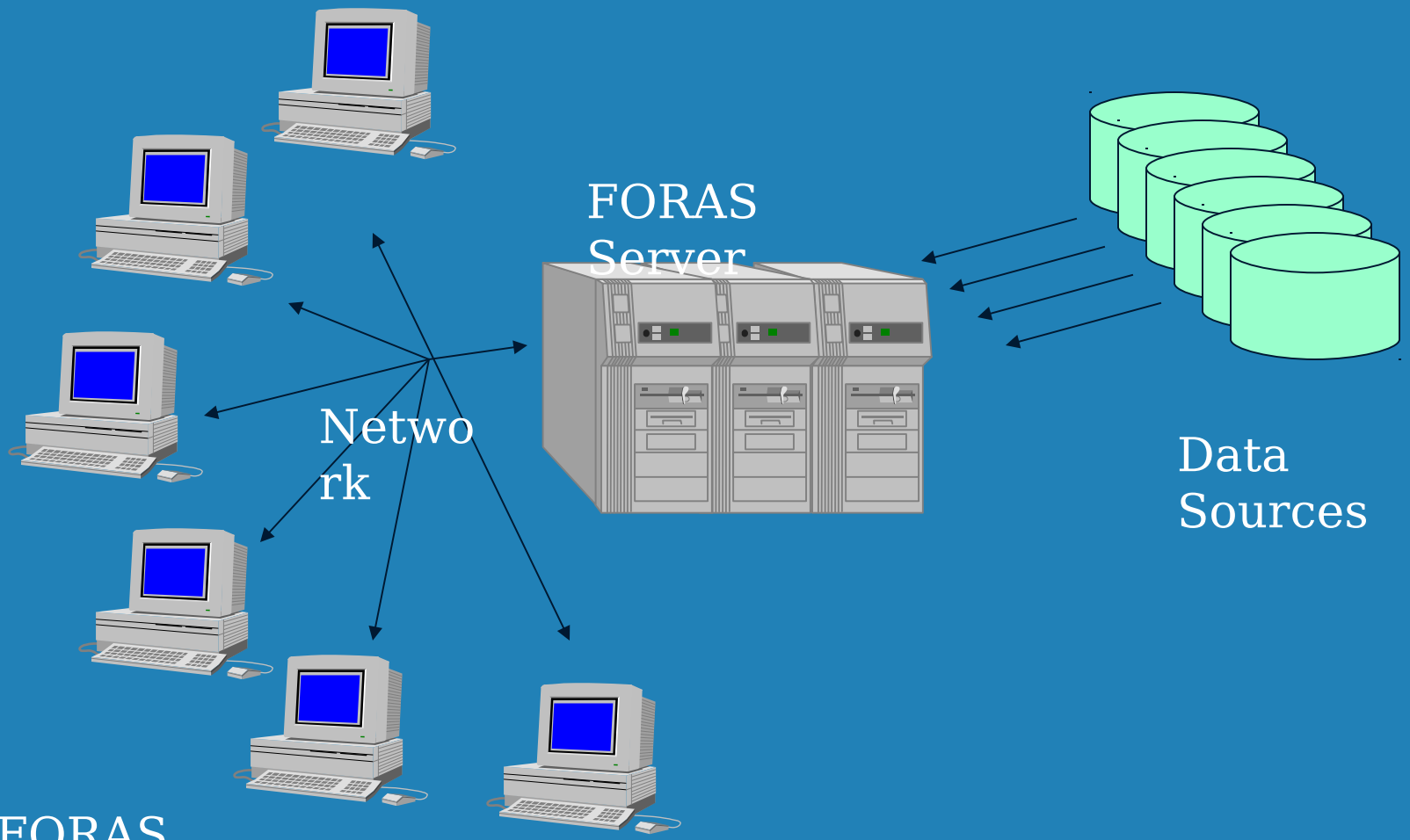
System

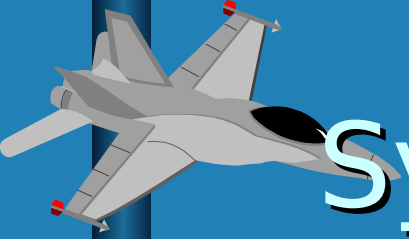
A system for the assessment of risks associated with flight operations:

- Software
- Network connectivity
- Online data sources
- Reporting system



The System

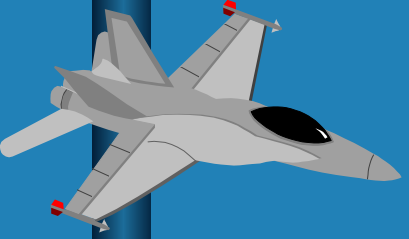


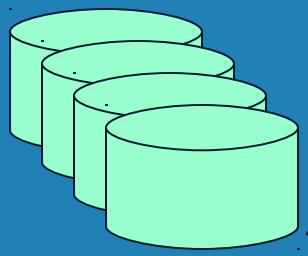


System Feature Overview

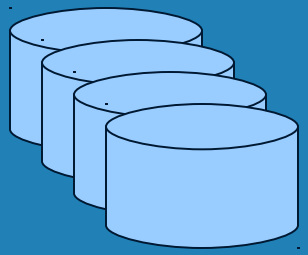
- Client-server model makes results available organization-wide: central processing, distributed reporting.
- Modular design allows simple model updates: plug-in modules can quickly add and update risk structures.
- Self-training: relative risk attribute weights dynamically adjusted according to feedback.

The System





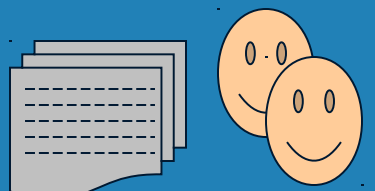
Real-time/
dynamic data

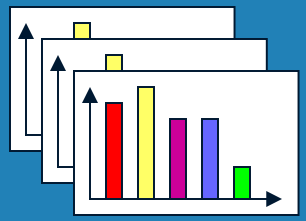


Systemic/
Static data

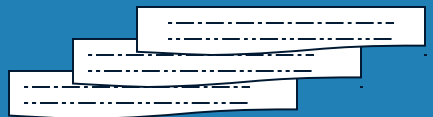
FORAS

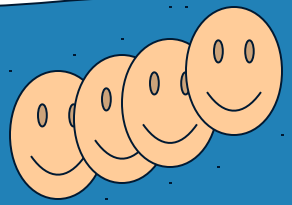
Summary
analyses





Real-time
analyses

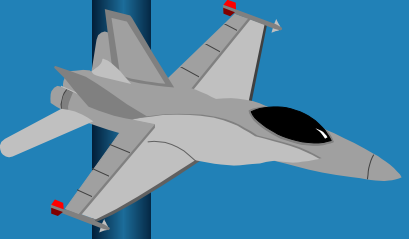




Data:
Types/sources

Model
- Software/hardware
- components
- development process

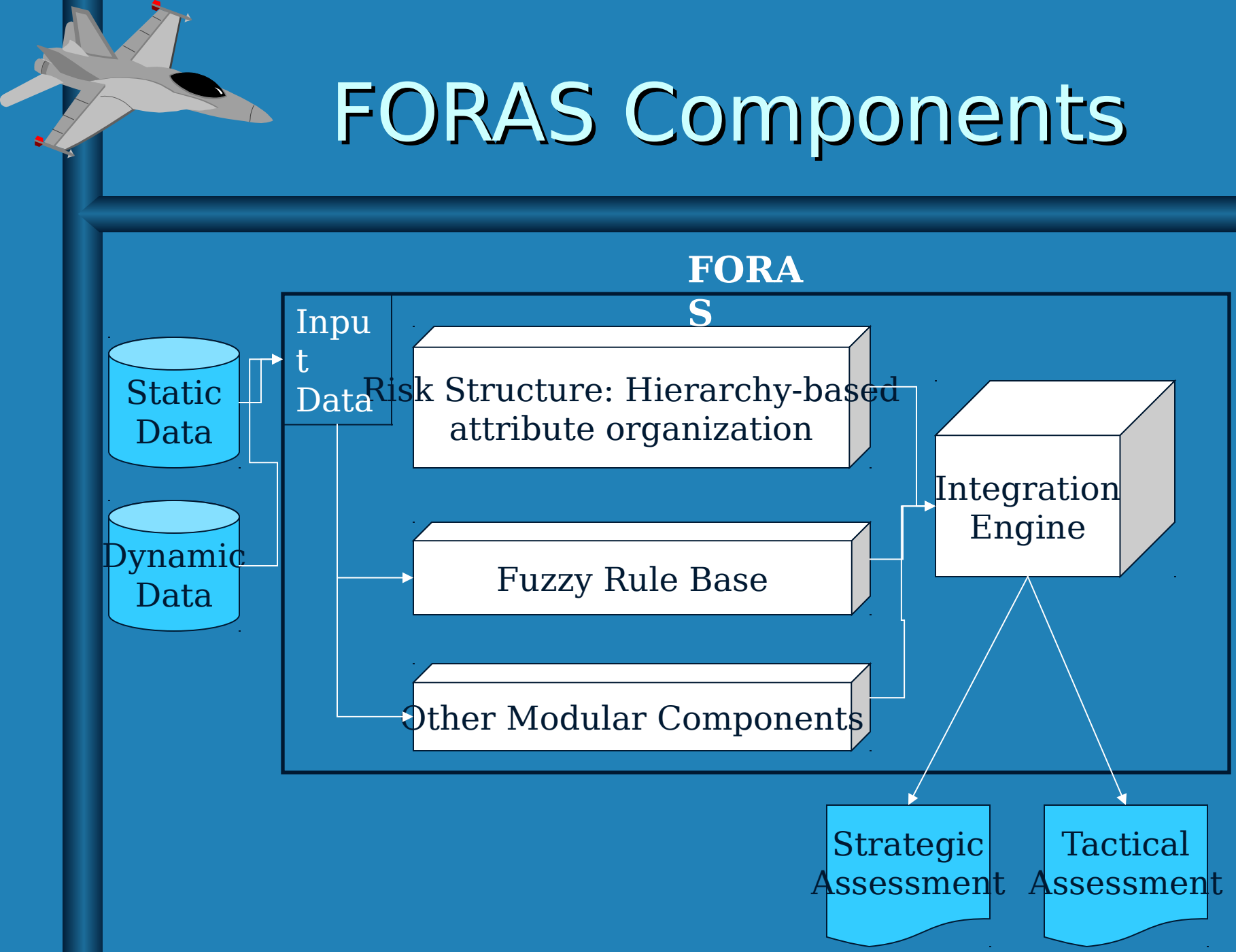
Users, reporting systems



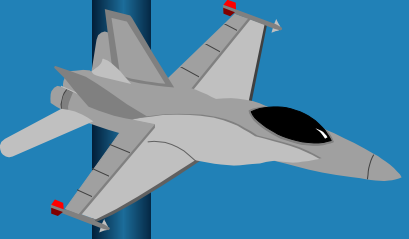
Data Types

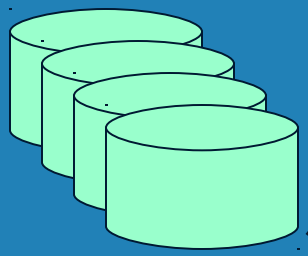
- Real-time/dynamic:
  - e.g., current weather conditions/forecasts, current airport capacity, crew assignments, equipment, air traffic, etc.
- Systemic/static:
  - e.g., climatological, airport equipment/terrain/capacity, management safety policies, crew scheduling policies, crew experience, dispatch experience, etc.

FORAS Components

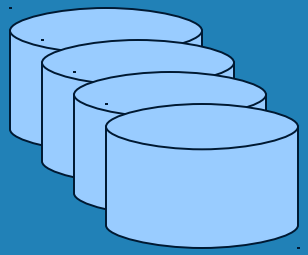


The System





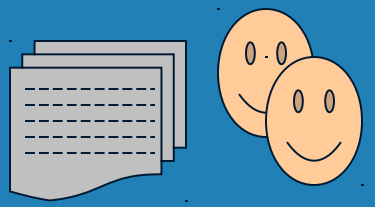
Real-time/
dynamic data

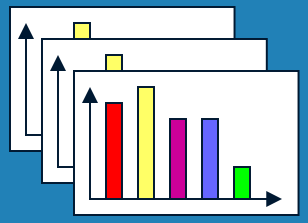


Systemic/
Static data

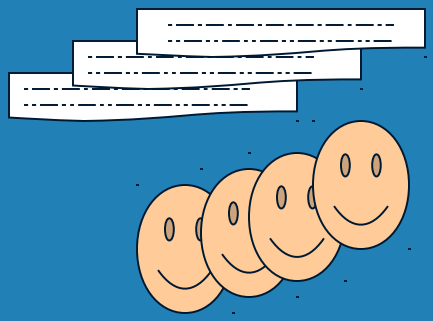
FORAS

Summary
analyses





Real-time
analyses



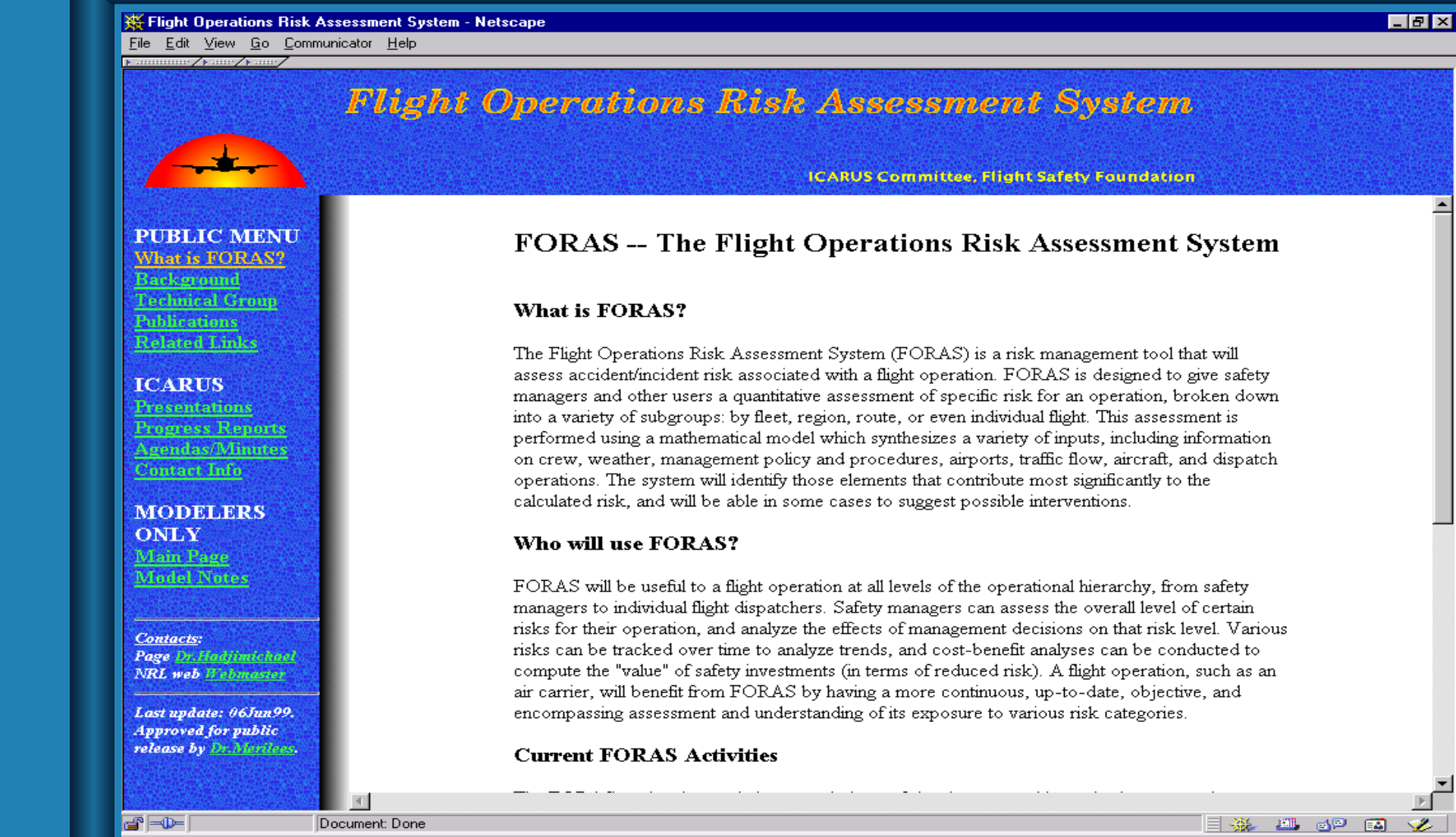
Data

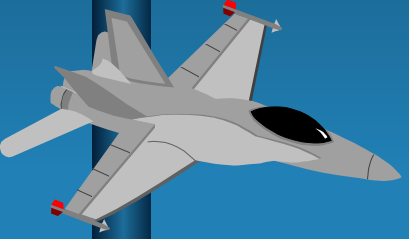
Model

Users, reporting systems

FORAS Web Site

http://www.nrlmry.navy.mil/foras

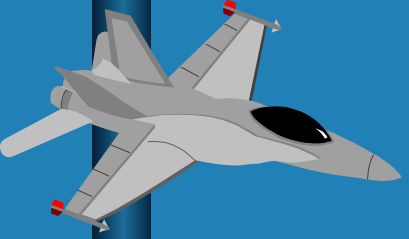




Flight Operations Risk Assessment System

FORAS

Technical Product Demonstration

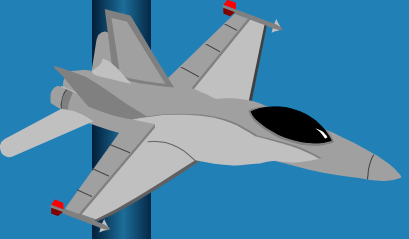


Representing a Rule Conclusion

- Sugeno Method: Risk contribution for each rule is of the form $R = a_0 + a_1 x_1 + a_2 x_2$
- Example: If In-type hours are *medium* and block time is *high* , then

$$R = 0.8 - 0.6 x_1 - 0.2 x_2$$

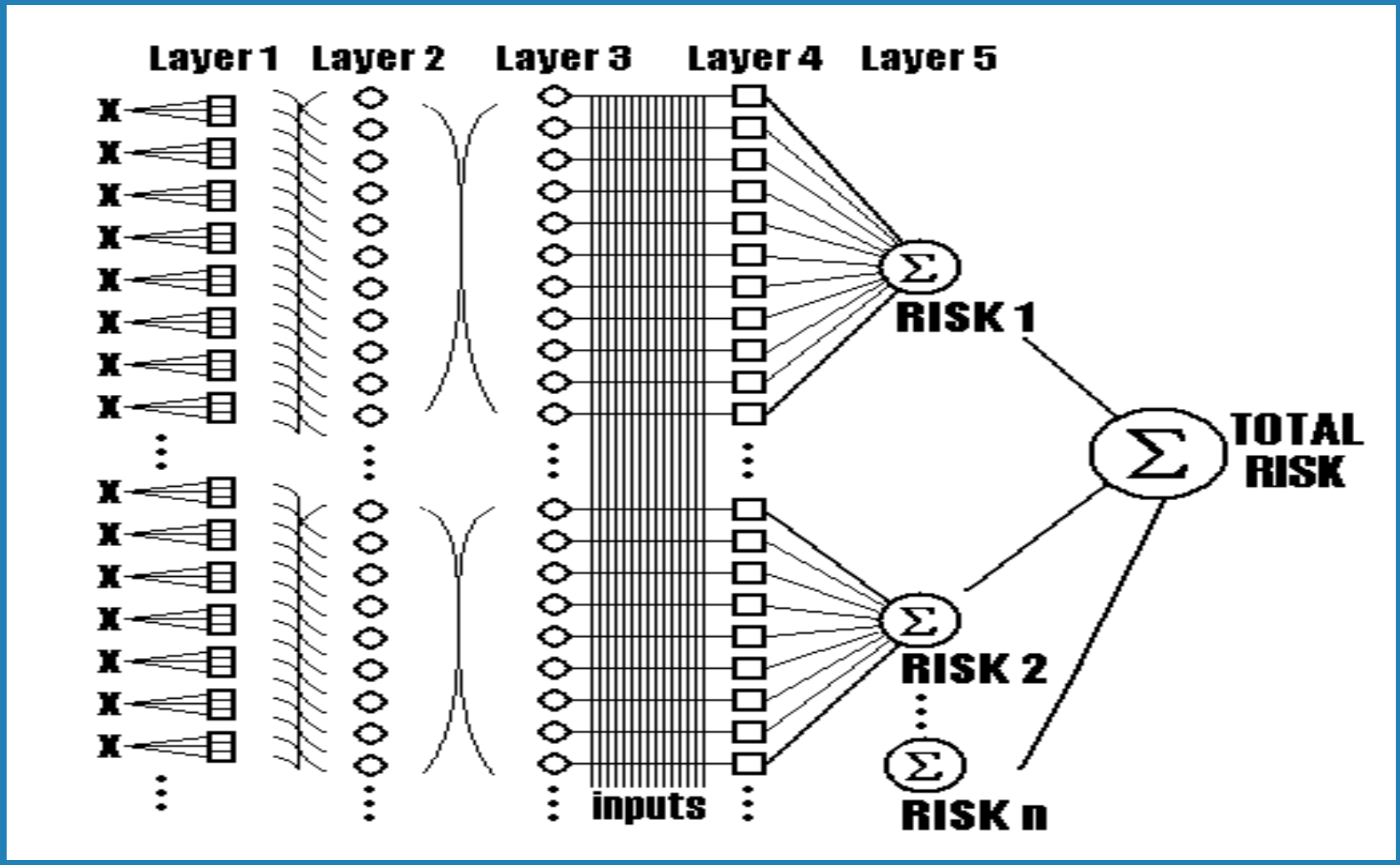
- Normalized inputs: x 's
- Conclusion parameters: a 's
  - Parameters are "trained" to adapt to the risk estimates for a set of flights

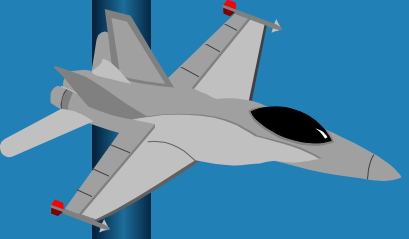


Model Advantages

- Apply to all risk categories
- Customizable to different safety environments
- Adapt to technological and procedural changes in airline environments
- Use data and expert judgments in a unified model

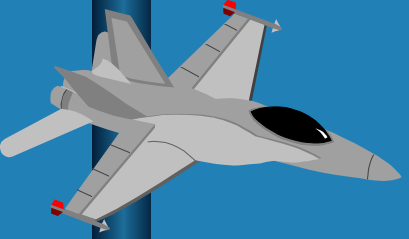
Network Model





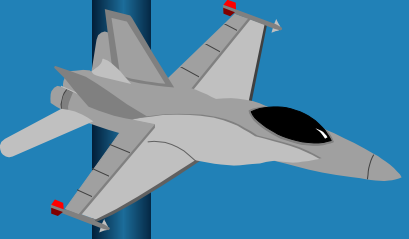
Sample Model Inputs

- Weather (detailed]
- Light/Dark Conditions
- Significant Terrain
- Presence/Type of GPWS
- Management & Organization
- Operations Training
- Scheduling Practices
- Presence of TAP
- Experience Measures
- Recency Measures
- Airport Classification
- Critical Task Times
- English Language Skills
- Deferred Maintenance
- NOTAMS



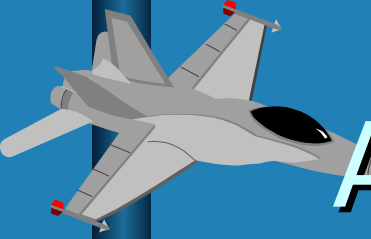
What Inputs are Most Relevant?

- Classifying inputs in Phase I
  - CFIT checklist
  - AHP (Phase I)
- Classification Refinements in Phase II
  - Indirect capture of essential elements:
    - Example: “time of day” - provides indirect information on weather, crew performance, or ATC functionality
- Issue of economizing inputs



Model Parameters

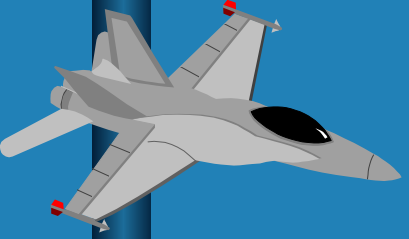
- Risk dependent upon
  - Raw inputs
    - Requires highest and lowest possible values
    - Normalized to 0 -1 scale
  - Shape of membership functions
    - Capability to modify membership functions
  - Representation of rule conclusion
    - All rules may not require all inputs. This would reduce complexity.



An Explosion of Variables

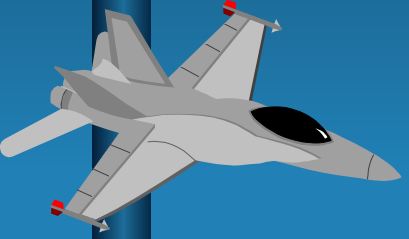
Number of membership functions for each input =3

#Inputs	#Nodes	#α
2	36	27
3	94	108
4	260	405
5	750	1,458
6	2,212	5,103
7	6,590	17,496
8	19,716	59,049
n	$4n+3^{n+1}+1$	$(n+1)3^n$



Model Issues

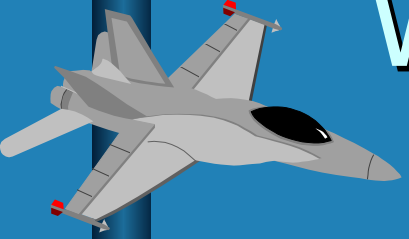
- Accomodating more input variables
  - Reducing number of model parameters
- Use of training data and testing data
  - Model development used artificial data
  - Different data sets must be used to train and to test
- Generating target values
  - Model development used artificial targets
  - Strategies for simplifying target acquisition
- Validation strategies



WEATHER COMPONENT *OVERVIEW*

August 1999

AT&T Morristown



WEATHER AS A PART OF FORAS

- Weather plays a significant role in certain aviation risk factors.
- The FORAS system must be sensitive to weather changes that change risk profiles.
- In the phase-2 system, historical weather information and statistics will be used.
- The historical weather data will provide a baseline until real-time weather is available.

WEATHER AS A PART OF FORAS

- WEATHER DATA
  - Observations
  - Forecasts
  - Forecast skill
  - Climatology
- APPLICATION
  - Decoding
  - Interpretation
  - Climatology Analysis
  - Forecast skill analysis

Photo by Greg Thompson

AN IMPORTANT ROLE IN RISK ASSESSMENT *AN EXAMPLE*

- CLIMATE DATA:

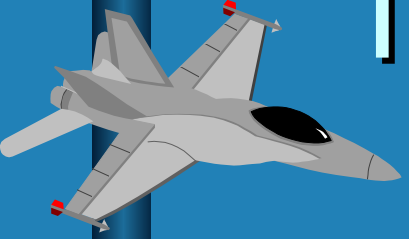
  Historical weather data shows that on average fog rolls into SFO most mornings and lingers until noon.

- FORAS INTERPRETATION:

  Morning flights at SFO should have more CFIT risk than afternoon flights due to the increased occurrence of fog conditions.

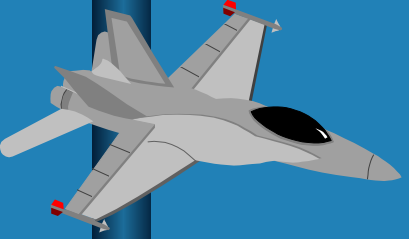
AN IMPORTANT ROLE IN RISK ASSESSMENT

- Forecasted Weather: Inaccurate forecasts will lead to higher risk as users of the forecast may ignore information or users may make incorrect decisions based on the inaccurate forecast.
- Hypothetical example:
  - Heavy rain is forecasted by NWS at ORD.
  - When heavy rain is forecasted by NWS at ORD, heavy rain occurs X percent of the time.



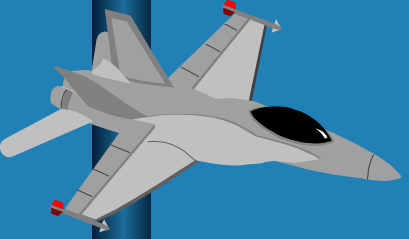
Three Tiers of Weather Information

- Climatology: A statistically based averaging of local weather over specified time periods.
- Weather Data Collection: Acquiring and decoding of current forecasts and observations for Phase II development and verification.
- Forecast Verification: Re-calibration of forecasted weather to reflect the expected outcomes associated with various forecasts.



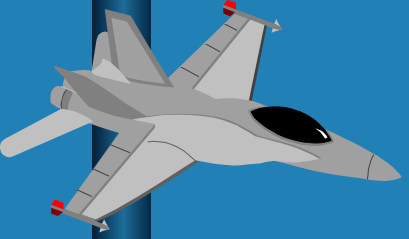
Summary of Work Accomplished

- **Weather Data Structure and Data Sources identified and reside at NCAR.**
- **Work Plan developed in response to FORAS needs and future goals.**
- **An aviation weather climatology for Denver, Chicago, San Francisco and Washington Dulles (UAL hubs) has been created with coding that is easily extendable to approximately 250 U.S cities.**



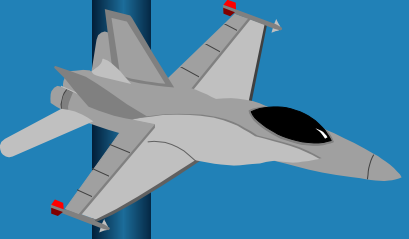
Climatology

- Percent occurrence of specified weather phenomenon
- Parameters
  - Flight Conditions
  - Hourly Changes in Flight Conditions
  - Ceiling Heights
  - Visibility
  - Runway Visual Range
  - Precipitation and Intensity
  - Altimeter Setting
  - Temperature Minus Dewpoint
  - Temperature
  - Wind Speed and Direction
  - Gusting Winds
  - Variable Winds
  - Hourly Changes in Wind Speed
- Time Periods
  - Hourly by Month/over Year, Tri-hourly by Month/over Year, Daily over Year, Weekly over Year, Monthly over Year, Yearly



METAR and TAF Data Collection

- Establishing the format and content of data for use within the overall FORAS product.
- Collecting data for use in FORAS system development and verification, as well as in the Forecast Verification Analysis.
- Currently collecting NWS TAFs and METARS and also United Meteorology Department's airport hub TAFs.

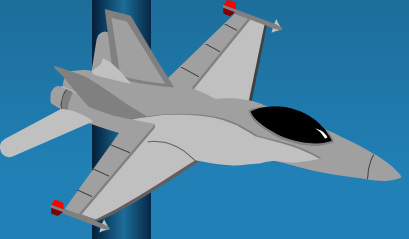


Forecast Verification

- An analysis to determine the conditional probability of weather occurrence given its forecast. Analysis will include location, time, weather type and forecast type. For example,
  - NWS TAF for ORD predicts light snow.
  - Historical data analysis shows that there is X% actual occurrence of light snow given this forecast.
  - FORAS INPUT AND INTERPRETATION:
    - Actual probability of the occurrence of light snow given above forecast.
    - Risk caused by incorrect forecasting.

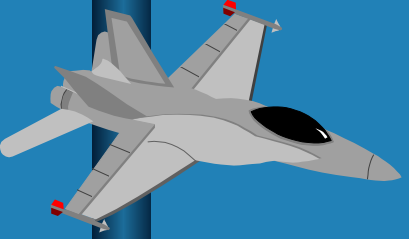
QUESTIONS?

Photo by Greg Thompson



Flight Operations Risk Assessment System

Industry/Data Collaborations

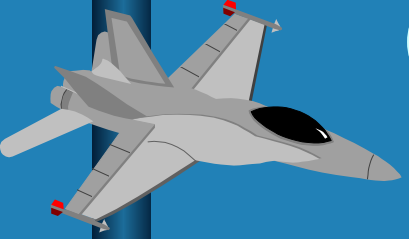


Industry Collaborators

- United Airlines
- Airbus Industrie
- Pilots from other airlines - major, cargo, regional
- Delta Airlines - Dispatchers
- ATC Controllers - Daytona Beach and Monterey
- Aviation Professionals - ERAU
- Weather Experts - NCAR, NWS

What Has UAL Partnership Provided?

- Expert elicitation sessions involving
  - Pilots (sessions at UAL Flight Training Center)
  - Dispatchers (including air traffic coordinators)
- Data discussions with Information Services
- Discussion and feedback
  - Pilots, cabin attendants, safety personnel, dispatchers, meteorology, flight operations personnel
- Modeler liaison - Grant Sullivan
- Jumpseat time - Diana Boyd



Collaboration with Airbus Industrie

- Airbus has a product (LOMS) to measure performance using FOQA-type inputs
- Potential for LOMS-related data to be used within FORAS
  - to provide targets for selected flights
  - to provide inputs for real-time model
- Opportunity for international airline partner to provide training and testing data
- Advantage for Airbus - enhancement of LOMS

Adaptive Feedback Rule Base Generation -- FORAS + LOMS

Operational Data

DFDR Data

FORAS Inference Engine

LOMS Event Detection

Fuzzy Rule Base

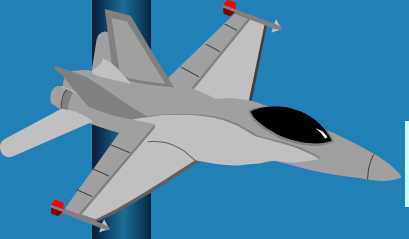
FORAS Assessment

LOMS Assessment

Error and Feedback Calculation

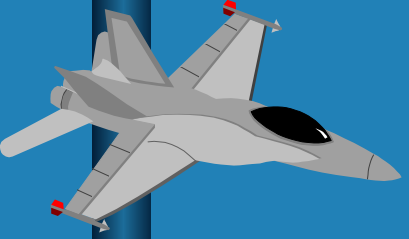
Feedback

Final, Refined Fuzzy Rule Base



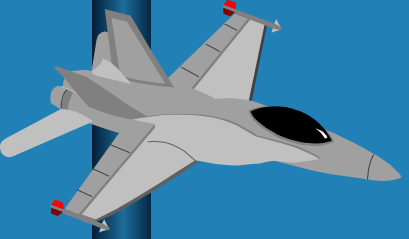
Immediate Data Needs

- Identify an airline that is willing to provide data
  - Option 1 - provide de-identified flight information to FORAS modelers for training and testing of model; or
  - Option 2 - firewall data and provide resources for airline personnel to conduct analysis guided by FORAS modelers
  - What data?...



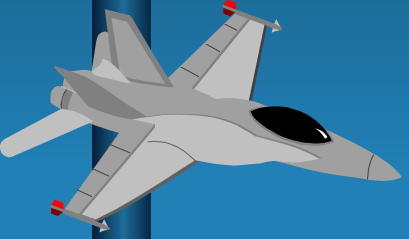
Specific Data Requirements

- One record per flight
- Under current expectations for inputs…
  - At least 10,000 flights required for training
  - If limited to testing, only 2,000 flights required as long as flights represent all input combinations
- For flexibility in training and testing, more flights are desired



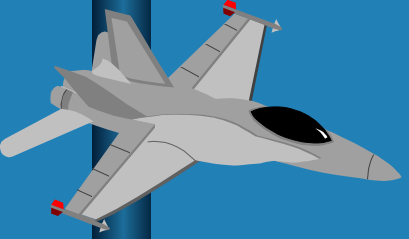
Model Validation

- Source of expert judgments: pilots or others?
- Two strategies under consideration:
  - ① Collect risk estimates with experts ranking flights as high, medium, or low risk; compare results with model output
  - ②Collect risk estimates with experts providing numerical estimates of CFIT risk; compare results with model output
- Use of aircraft performance data as target value?



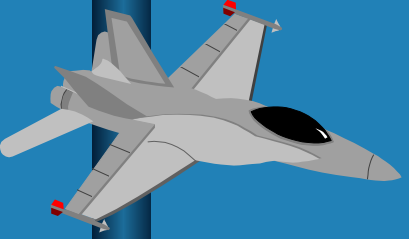
Flight Operations Risk Assessment System

FORAS Future Plans/Requirements



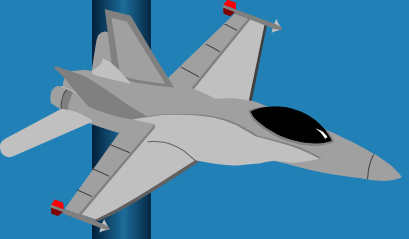
End of Phase II Goals

- Develop prototype user interface
- Complete development of prototype
- Identify and use data for model training and testing



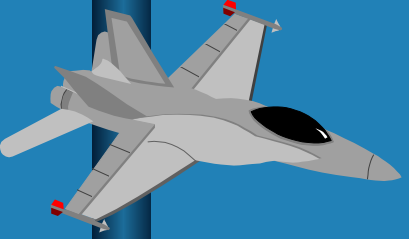
Phase II Model Inputs

- Weather inputs
  - Meteorological conditions
  - Thunderstorm presence and intensity
  - Variability of flight conditions
- Airport classification
- Departure and arrival airports
- Time of day



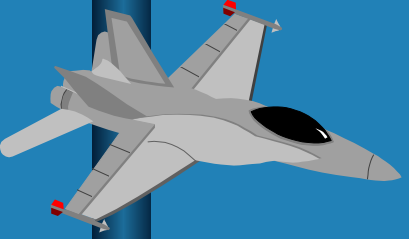
Additional Inputs (data permitting)

- Pilot In-type experience
- Availability of EGPWS
- Management safety survey
  - Organizational structure
  - Training programs



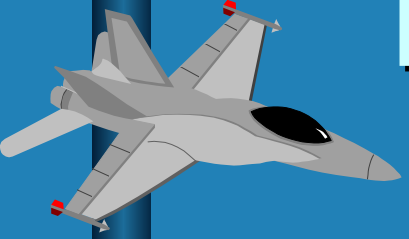
Future FORAS Development

- CFIT work
- Additional model refinement
  - Accommodate larger number of inputs
  - Incorporate “clustering” ability
  - Modularize inputs
  - Incorporate technique for updating model
    - batch processing
    - online adaptation



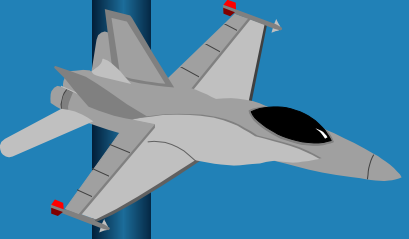
Future FORAS Development

- Use of technique to develop overall accident relative risk assessment system
  - Identify “significant” accident risk categories
  - Identify inputs for each significant risk category
  - Develop additional membership functions, as required
  - Develop expert system functionality for risk mitigation



Future Goals for FORAS Weather

- Further research on weather phenomena associated with additional risk categories (e.g.turbulence)
- Comprehensive forecast accuracy study
- Climatology expansion and further analysis
- Creation of an expanded aviation weather database necessary to support other risk categories
- Evaluation of weather needs for real-time FORAS system



Extension to Other Environments

- International operations
- Military
- Regional and commuter airlines
- General Aviation